3B.4 CLOUD-RESOLVING MODEL SIMULATION OF LARGE ENSEMBLE OF CLOUD SYSTEMS FROM EOS SATELLITE OBSERVATIONS AND COMPARISON WITH THE ECMWF CLOUD MODEL

Kuan-Man Xu[1*], Takmeng Wong[1], Anning Cheng[1,2], Zachary Eitzen[1,3], and Bruce A. Wielicki[1]
[1]NASA Langley Research Center, [2]Hampton University, [3]Colorado State University

1. Introduction

Representation of clouds and their radiative feedback processes is still the weakest component of current general circulation models (GCMs). To improve the predictive performance of current GCMs, a new systematic method for evaluation and improvement of cloud parameterizations has been proposed (Xu et al. 2002). Specifically, this new technique classifies satellite data into distinct cloud systems defined by their types (e.g., trade cumulus, stratus, and deep convections). These observed cloud systems are then matched with nearly simultaneous atmospheric state data from the European Center for Medium-range Weather Forecasts (ECMWF). The atmospheric data are also used as inputs for cloud model (e.g., single column cloud models, cloud-resolving models and large-eddy simulation models) simulations. The cloud model results are then compared with satellite observations. Instead of using the traditional gridded-mean comparison, this new approach takes cloud model evaluation into tests of large statistically robust ensembles of matched atmospheric states ==> cloud model ==> satellite cloud system data comparisons, emphasizing on evaluating the higher-order distributions of subgrid-scale characteristics of cloud systems between satellite observations and cloud models.

This paper presents some preliminary results from cloud-resolving model (CRM) simulations of tropical convective systems identified by EOS (Earth Observing System) satellites. The goals are twofold: 1) to compare CRM simulations with satellite observations and 2) to evaluate the ECMWF predicted cloud fields with satellite observations and CRM simulations.

2. Satellite data and cloud objective analysis

The satellite data used in this study are from the Single Scanner Footprint (SSF) data set from NASA's Clouds and the Earth's Radiant Energy System (CERES)/Tropical Rainfall Measurement Mission (TRMM). The CERES SSF combines instantaneous CERES broadband radiative flux observations with scene information derived from the Visible/Infrared Scanner (VIRS) cloud imager on TRMM. Major parameters used for this study include cloud amount, height, temperature, pressure, optical depth, emissivity, ice and liquid water path and particle size information, as well as broadband shortwave (SW) and longwave (LW) radiative fluxes from the top of the atmosphere.

The satellite cloud objective analysis uses the CERES SSF data to group cloud properties and radiative flux observations into a contiguous region of the earth, each with a single dominant cloud type. The shapes and sizes of these cloud systems are determined by the data. The criteria used for identifying tropical convective systems are 1) cloud height of at least 10 km, 2) visible optical depth of at least 10, 3) cloud amount of 100 percent, 4) latitudes within 25° of the Equator. Radiative and optical parameters from the CERES SSF footprint data that fall within the boundary of the cloud systems are used to compute the probability density functions (PDFs) for comparison with ECMWF predicted cloud fields and CRM simulations. For the March 1998 period, a total of 29 tropical convective cloud systems have been identified by this cloud objective analysis, with sizes ranging from 300 to 600 km in diameter. These cloud systems are matched with nearly simultaneous ECMWF atmospheric state data, as well as large-scale advective tendencies which are used to drive the CRMs.

3. ECMWF predicted cloud fields

The ECMWF data also contain a set of predicted cloud fields, which includes the vertical profiles of cloud water mixing ratio, cloud ice mixing ratio and cloud fraction. Since the ECMWF grid size (0.5625°x0.5625°) is much larger than the CERES footprint size (from 10 km x 10 km and larger), each ECMWF grid is further divided into smaller subgrids in order to properly compare the statistics of ECMWF predicted cloud fields with the satellite observations and CRM simulations. In this study, the maximum-random overlap assumption is used to distribute the ECMWF cloud fields horizontally and vertically (Klein and Jacob 1999). The broadband radiative fluxes and radiative properties of each ECMWF subcolumn are obtained using radiative transfer parameterization from the Fu-Liou radiation codes (Fu and Liou 1993). Same criteria used for identifying satellite cloud systems, in particular, the first two criteria described above, are then used to select the ECMWF subgrids of cloud and radiation fields for computing ECMWF PDFs for comparisons with observed and CRM generated PDFs.

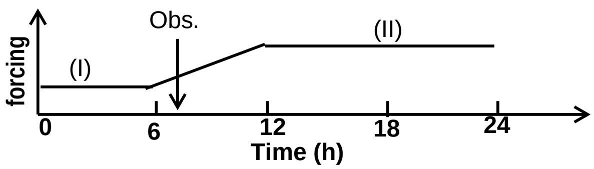
4. Cloud-resolving models

Two CRMs are used in this study, one is the LaRC2d, better known as UCLA/CSU model (Krueger 1988; Xu and Randall 1995) and the other is the LaRC3d, which is based upon the Advanced Regional Prediction System (ARPS; Xue et al. 2000) with the addition of the third-order turbulence closure from the former. Both models include five-phase bulk cloud microphysics parameterizations and broadband radiative transfer schemes. However, the dynamical structures are differ-

Corresponding author address: Dr. Kuan-Man Xu, Mail Stop 420, NASA Langley Research Center, Hampton, VA 23681-2199; email: k.m.xu@larc.nasa.gov.

ent between the two models, i.e., an anelastic system for LaRC2d but a compressible system for LaRC3d.

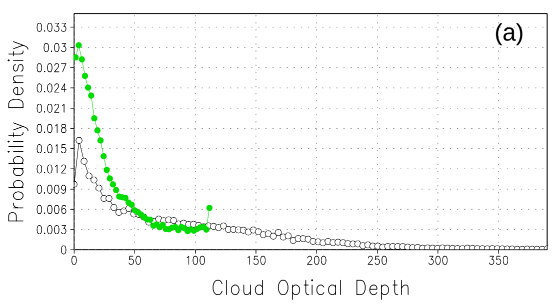
Each cloud simulation is run for a 24 hr physical time driven by the advective tendencies obtained from ECMWF data. The simulation is initialized with a horizontally homogeneous sounding averaged over a square area three times as large as the observed cloud system and at least 6 hr before the cloud system was observed. The advective tendencies averaged over the same area at two different times (I: earlier; II: later), 6 hr apart from each other, are used to drive the models (see the illustration below). The latter time is closer to the observation.

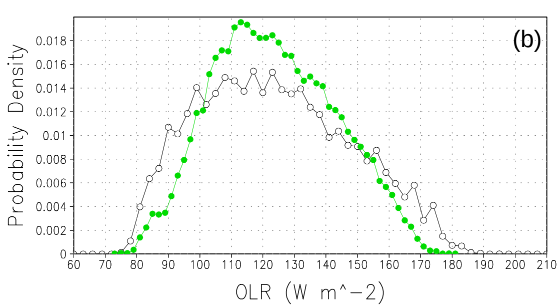


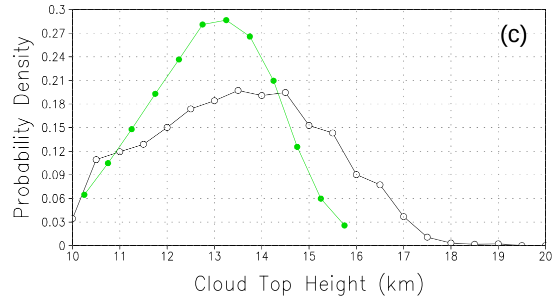
The outputs from the CRM simulations are analyzed in a similar fashion to those of the satellite and ECMWF data. The results from the last 12 hr of the simulations are used to obtain statistical and domain-averaged quantities for comparisons. The former requires the selection of CRM columns that satisfy the same criteria used in the cloud objective analysis.

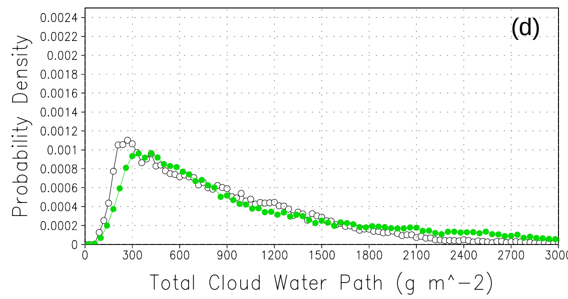
5. Preliminary Results

PDFs results for selected parameters, including (a) cloud optical depth, (b) outgoing LW flux, (c) cloud top height, and (d) total cloud water path, are shown in the panels below for both the ECMWF predicted cloud fields (open-circle lines) and the CERES SSF observed cloud fields (solid-circle lines). The PDFs are computed from all 29 cloud cases combined. These panels show strong similarities between CERES SSF and ECMWF data,



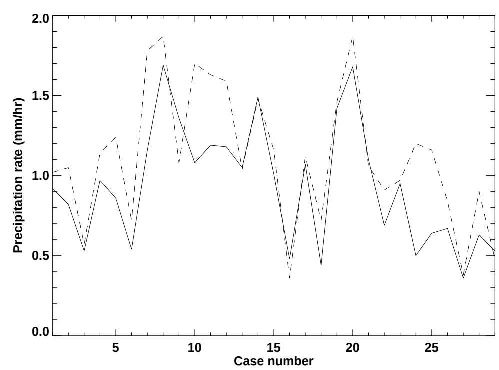






but differences are not totally negligible. For example, cloud top heights/outgoing LW fluxes from the ECMWF cloud fields are higher/broader-distributed than those from the satellite observations, respectively.

The same 29 cases have been simulated with the LaRC2d CRM, but similar analyses to those presented above have not been completed. The plot below shows a comparison of ECMWF (solid line) domain-averaged precipitation rates against those from LaRC2d CRM (dashed line). The agreement is very good between them for most of the 29 cases. More comparisons, including LaRC3d results, will be shown at the meeting.



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